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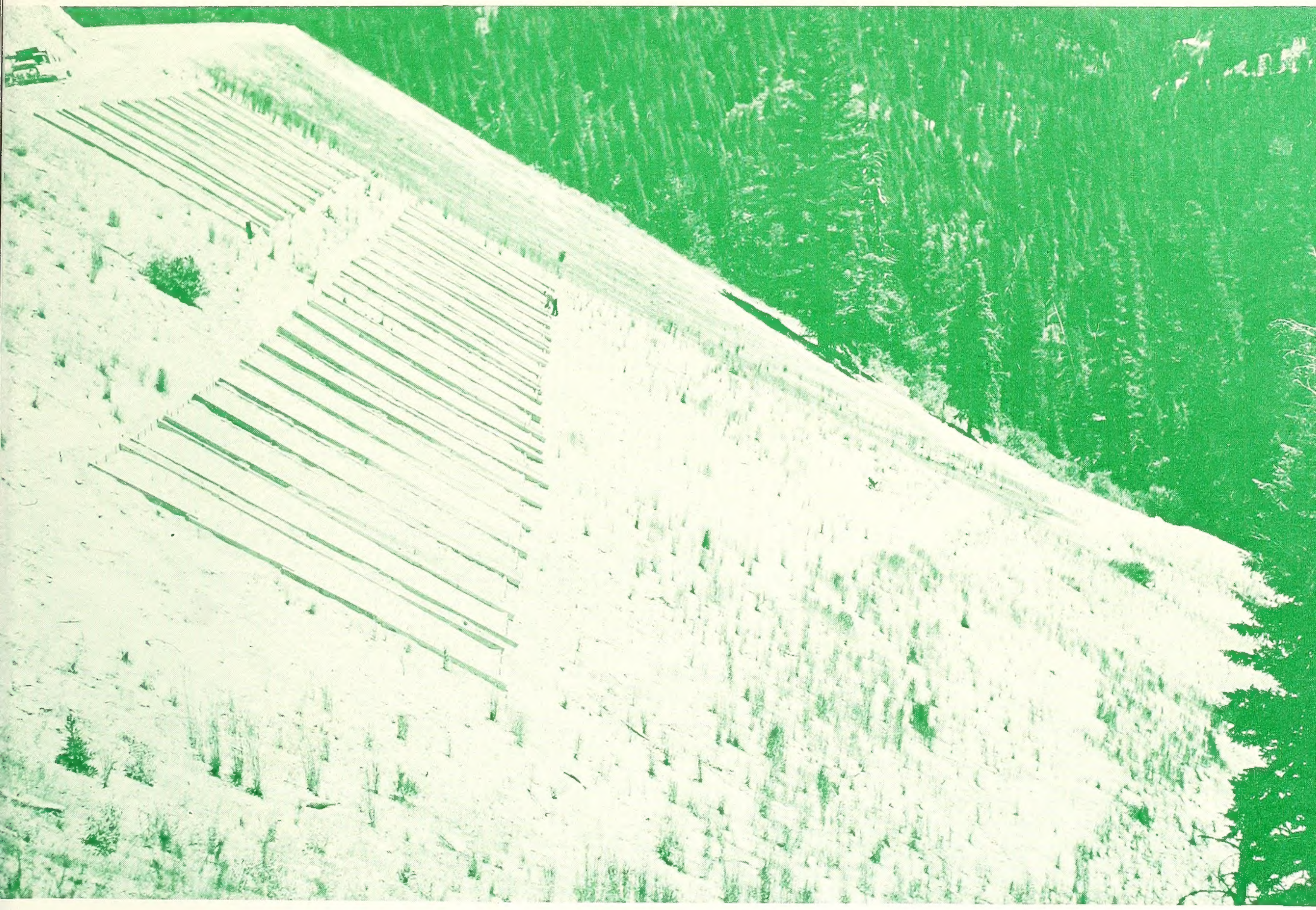

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Ogden, Utah 84401

The Author

WALTER F. MEGAHAN is Principal Research Hydrologist and Leader of the Idaho Batholith Ecosystems Research Work Unit in Boise, Idaho. He holds bachelor's and master's degrees in Forestry from the State University of New York, College of Forestry, at Syracuse University, and a doctoral degree in Watershed Resources from Colorado State University. He served as Regional Hydrologist for Intermountain Region of the USDA Forest Service in Ogden, Utah, from 1960 to 1966 and has been in his present position since 1967.

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Deep-rooted plants for erosion control on granitic road fills in the Idaho Batholith

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Roger R. Bay, Director

Abstract

Numerous studies suggest that ponderosa pine (Pinus ponderosa Laws.) should reduce mass erosion hazards on road fill slopes. A study, designed with 3 replications of 10 treatments on 1/200-acre study plots, was conducted to evaluate how well ponderosa pine survives, grows, and reduces surface erosion on granitic road fills in the Idaho Batholith. The study was installed in 1968 and continued through 1972. Tree survival averaged about 97 percent after four growing seasons. Fertilizer increased planted tree growth an average of 95 percent during the year of peak effect. Tree planting, coupled with straw mulch and erosion netting, reduced erosion an average of about 95 percent over 3 years. Planted trees alone provided surprisingly large reductions in erosion, ranging from 32 to 51 percent. Planting ponderosa pine at a spacing of 3 by 3 to 4 by 4 feet is recommended as an erosion-control measure for granitic road fills in the Idaho Batholith.

CONTENTS

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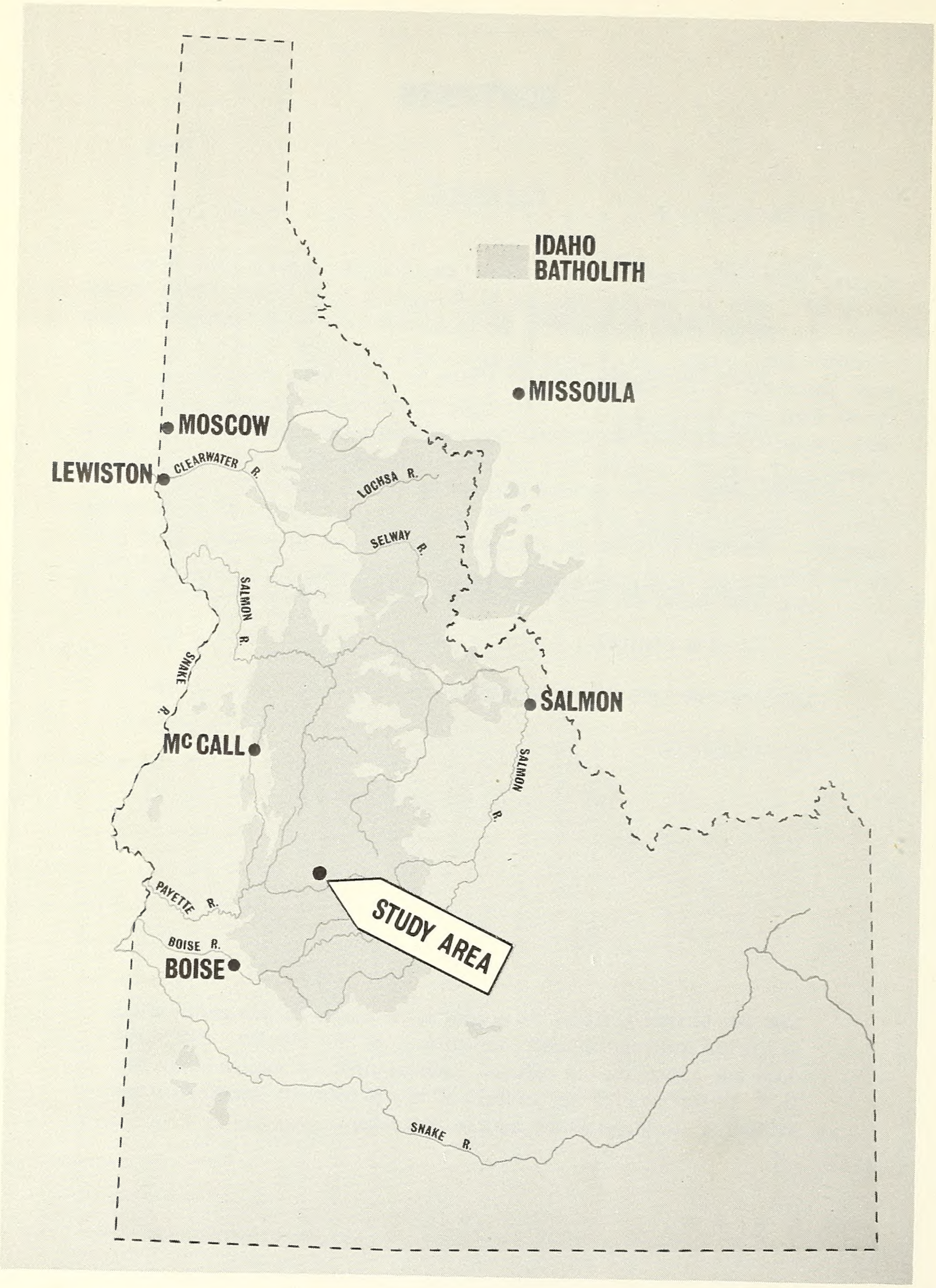

Figure 1.--Location map showing the Idaho Batholith and the study area.

INTRODUCTION

The Idaho Batholith is a 16,000-square-mile expanse of granitic rocks located in central Idaho (fig. 1). Much of the region is characterized by steep slopes and shallow, coarse-textured soils overlying granitic bedrock. Soils of this type have been shown to be extremely erodible (Anderson 1954; André and Anderson 1961).

The potential for erosion following road construction on side slopes in the Batholith is greatly increased within and sometimes beyond the road prism. Some factors causing the increase are: interruption of subsurface flow; removal of vegetative cover; destruction of natural soil structure; cut and fill slopes, which necessarily exceed the original slope gradient; and decreased infiltration rates on portions of the road. Megahan and Kidd (1972) reported on a 6-year study of erosion from secondary logging roads in the Zena Creek area of the Payette National Forest. Erosion on the area disturbed by road construction averaged 770 times greater than that occurring on nearby undisturbed watersheds.

In general, the erosion potential probably is increased more on the fill portions of a road than on the cut portions. Hydrologic analysis of the Zena Creek logging study area conducted by the Payette National Forest in 1966 showed that surface erosion on fills was an estimated 1.75 times that on road cuts. Evaluations also showed that material moved by mass erosion (landslides) amounted to almost as much as that resulting from surface erosion. Most landslides in the Zena Creek area occurred in the fill portions of roads.

Bethlahmy and Kidd (1966) reported that grass seeding, coupled with straw mulch, bound in place by erosion net, reduced surface erosion on a granitic road fill by about 98 percent the first year. However, the Payette National Forest hydrologic analysis on Zena Creek showed that an established grass cover did not prevent mass erosion of road fill surfaces. In some cases, as soon as the fill became sufficiently saturated with moisture, it "melted" and flowed down the hillside like wet concrete. The conclusion was that grass roots cannot bind a massive sandy fill together if the fill is standing at greater than its natural angle of repose.

Corbett and Rice (1966) found a similar situation in southern California. Mass movement was five times greater on brushlands converted to grass than on unconverted brushlands. Apparently, the deep-rooted brush provided more stability than that maintained by the grass after conversion. Bishop and Stevens (1964) and Swanston (1967) stated that mass erosion was reduced by tree roots on shallow soils in southeast Alaska. Gray (1969) summarized the literature and showed that trees tend to reduce mass erosion by mechanical reinforcement from roots, soil moisture depletion from transpiration, and providing a surcharge from the weight of the trees. Trees can have a destabilizing effect because of windthrowing and root wedging; however, he concluded that the net effect of tree cover is to increase mass stability.

In summary, a major problem associated with road construction on steep granitic lands is that of stabilizing road fills with regard to *both* surface and mass erosion. Research has shown that surface erosion on road fills can be greatly reduced and areas of mass erosion can be stabilized by deep-rooted vegetation. Thus, the problem is to find a way of establishing vegetation that will reduce both types of erosion. Shrub planting presents possibilities; however, at the outset of this study, tree planting was the most logical solution. Tree planting is used extensively throughout the Southeast to successfully control surface erosion (USDA Agricultural Research Service 1967). The question arises as to which species is best suited for this purpose on Idaho Batholith lands. Preferably, the species used should be a native that (1) has a wide habitat range in the Idaho Batholith; (2) is well adapted to the mineral soils found in harsh, steep sites; (3) has a rapidly growing and extensive root system with a taproot if possible; and (4) is readily available as planting stock or seed, or both.

Ponderosa pine (*Pinus ponderosa* Laws.) is a species that meets most of the above requirements. This native species is naturally distributed over most of the Idaho Batholith (Munns 1938). It is found as a climax species on warm, dry sites or, more commonly, as a seral species on cooler, moister sites.

Road fills on granitic soils constitute harsh sites for vegetative growth and survival of most species. Coarse-textured surfaces can be hot during the summer because of the lack of plant cover and can dry rapidly, at least on the surface, during rainless periods. Curtis and Lynch (1957) showed that ponderosa pine survival and growth are most dependent on available soil moisture. They found that seedlings possessed the ability to withstand prolonged drought and high surface temperatures. Drought resistance was primarily due to rapid growth of the root system, especially the taproot. Tree growth was more rapid when water use by competing vegetation was minimized and when sunlight was maximized.

Road fills necessarily exceed the depth of the original soil, often on the order of two to five times or more. Summarizing edaphic requirements of ponderosa pine, Curtis and Lynch (1957) stated, the species probably reaches its best development on well-drained, deep, sandy gravel and clay loams. Olson and others (n.d.) found the most important soil-growth relationship for ponderosa pine to be a direct increase in growth with soil depth for three different kinds of soils. Similar results were found by Cox and others (1960).

The rooting characteristics of ponderosa pine are probably a causal factor of drought resistance and growth response. Ponderosa pine develops a strong taproot, that is considered to be deep (Kramer 1949). Curtis and Lynch (1957) stated that root growth is rapid and continues after cessation of top growth. They reported average lengths of 22.4 inches for roots on 1-year-old natural seedlings and 60.7 inches for 4-year-old seedlings on severely burned sites with southerly aspects on coarse granitic soils in Idaho. Similar results were found by Boldt and Singh (1964), who reported root depths on planted 2:1 ponderosa pine stock of 2, 4.9, and 6.4 feet, and 1, 2, and 4 years, respectively, after planting in Nebraska.

Based on the above studies of rooting characteristics, ponderosa pine seems to be morphologically well suited to providing mechanical stability for mass erosion on road fills, certainly better suited than grass. Use of this species for erosion control on road fills in the Idaho Batholith has other advantages. Ponderosa pine is a valuable commercial species throughout its range. In addition, planting stock is readily available from local nurseries, as is seed to a somewhat lesser degree. Finally, the silvics and forest management practices for ponderosa pine are known and accepted for the most part by land managers.

The present study was designed to evaluate the effect of ponderosa pine with and without surface amendments on surface erosion. Seeded grass plots were also included to provide a comparison with earlier studies. No attempt was made to evaluate decreases in mass erosion hazard due to tree planting because such studies are extremely involved and beyond the scope of present efforts and because studies elsewhere provide strong evidence that ponderosa pine should increase the mass stability of granitic road fills. Other objectives of the present study were to provide information on tree survival and growth and some insight into the basic surface erosion processes occurring on granitic road fills. This report will be devoted to evaluating the effects of ponderosa pine on surface erosion and to presenting data on tree survival and growth. Results pertaining to basic erosion processes will be reported elsewhere.

METHODS

Description of the Study Area

Study-site selection was guided by the following criteria:

1.--Variation in slope and aspect would be minimal among treatments within one replication;

2.--Replications would be on such harsh-site conditions as the south or west aspects of steep slopes with little or no vegetative cover;

3.--Some variation in slope and aspect could be tolerated among replications, but major variations would be avoided;

4.--Fill slopes would be large enough to accommodate at least one replication of contiguous treatments at a single location.

A suitable study site was found on a large fill slope on the Deadwood River road, Emmett Ranger District, Boise National Forest. The area is at an elevation of 4,700 feet on a steep, southwest-facing slope about 300 feet above the Deadwood River (fig. 1). A *Pseudotsuga menziesii/Physocarpus malvaceus* habitat type existed on the slope prior to road construction. (Habitat nomenclature from work by Robert D. Pfister, Robert Steele, and others in unpublished reports available at the Forestry Sciences Laboratory, Boise, Idaho.)

Specifications for the study site actually exceeded the criteria outlined above because the fill slope surface was uniform and averaged about 200 feet in length. This uniformity made it possible to install all three replications at the same location, under apparently similar site conditions, thus minimizing site contributions to experimental error (fig. 2). The road fill had a southwest aspect and a slope gradient ranging from 70 to 75 percent. The fill was constructed in 1957, about 11 years prior to the installation of this study. The area studied had been unsuccessfully seeded with grass at least twice prior to study installation. Failures may have been due to (1) excessive deposition of material resulting from road maintenance operations and from reconstruction of nearby portions of the road following an 11-day storm in December 1964; (2) surface erosion on the road fill; and (3) big game use. All plot surfaces were essentially bare at the time of study installation.

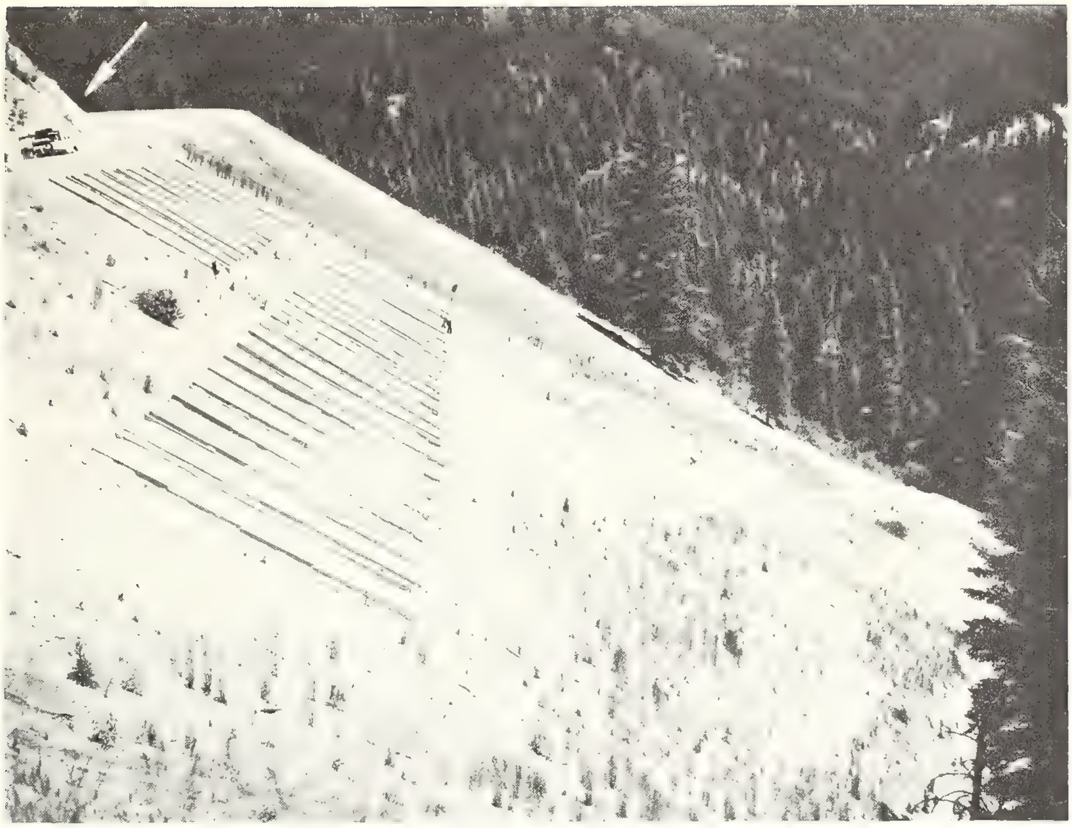

Figure 2.--The study site on a road fill approximately 200 feet long on the Deadwood River Road. Arrow points to vehicle, which provides a perspective of the size of the road fill. (Photo taken May 1968.)

Study Design and Installation

Plots used in the study were in a randomized block design with three replications. Each replication consisted of nine different treatments plus a control:

1. Control

2. Seed (grass) straw mulch, erosion net, fertilizer

3. Seed (ponderosa pine), straw mulch, erosion net, fertilizer

4. Seed (ponderosa pine), straw mulch, erosion net

5. Plant (ponderosa pine), 1.5 by 1.5-foot spacing, straw mulch, erosion net, fertilizer.

6. Plant (ponderosa pine), 1.5 by 1.5-foot spacing, straw mulch, erosion net

7. Plant (ponderosa pine), 2.5 by 2.5-foot spacing, straw mulch, erosion net, fertilizer

8. Plant (ponderosa pine), 2.5 by 2.5-foot spacing, straw mulch, erosion net

9. Plant (ponderosa pine), 1.5 by 1.5-foot spacing

10. Plant (ponderosa pine), 2.5 by 2.5-foot spacing

The seeded grass plot was included to provide a comparison of results to those of earlier studies. Seeded trees were used because initial treatment costs for tree seeding were less than those for tree planting. Fertilizers have been shown to produce dramatic increases in growth of ponderosa pine on forest soils elsewhere (Tarrent and Silen 1963; Cochran 1973). Road fills, especially those constructed from granitic materials, should show even greater response to fertilization. It was felt that spacing should be tested for effects on both growth and erosion. The spacings tested are closer than those normally used for reforestation; however, this was deemed necessary to minimize surface erosion on unmulched plots.

Other researchers have shown the advantages of plant cover, litter, or both for surface erosion control on granitic soils (Packer 1951; Bethlahmy 1967). Bethlahmy and Kidd (1966) found that straw mulch and netting were necessary to effectively reduce surface erosion on road fills seeded to grass during the early establishment period for grass. Because of a needle life of 2 years for ponderosa pine, the initial small-top size for planted or seeded trees, and the nature of the litter produced by such small trees, little erosion control was expected from planted trees, especially during the early years after planting. Thus, straw mulches were used on some planted tree plots. Mulches were expected to provide some additional benefit to tree growth by reducing soil temperatures, helping to reduce soil moisture evaporation, and discouraging competition from other species.

Erosion plots were 1/200 acre in size with dimensions of 7.25 by 30.0 feet. The long axis of each plot was oriented up and down the slope. Plots were constructed from 1- by 12-inch boards on the top and sides. A plastic-lined trough, 6 inches deep by 8 inches wide was placed at the downhill side to catch sediment. Inverted V-shaped deflector boards were installed on the uphill side of each plot to prevent rocks from rolling across the plots. Retainer boards were installed in the access strip between plots to prevent downslope soil movement during plot servicing. Straw mulch 1 to 2 inches thick was held in place by galvanized chicken wire (erosion net) stapled to the ground. Fertilizer used for planted trees consisted of one Treefeed Pellet (28-5-0) per tree placed at root level 2 inches uphill from the tree. This application amounted to 108.9 pounds per acre of nitrogen and 19.4 pounds per acre of phosphorus for the trees spaced 1.5 by 1.5 feet apart and 40.0 pounds per acre of nitrogen and 7.1 pounds per acre of phosphorus for the trees spaced 2.5 by 2.5 feet apart.

Plots were constructed in April 1968, as soon as snowmelt permitted. Following construction, straw mulch and erosion net were applied on appropriate plots. Trees were planted and fertilized the first week of May, in accordance with the experimental design. Unfortunately, trees were planted about 1 month later than the optimum time for planting at the site because of the time required for plot preparation. The 2-0 planting stock, which was obtained from the Lucky Peak Nursery near Boise, Idaho, was derived from local seed sources. Appropriate plots were seeded to grass and trees in October 1968. Grass species mixed in equal proportions were seeded by a cyclone seeder at a rate of 50 pounds per acre. Species used in the study were Topar pubescent wheatgrass; Tualatin oatgrass, Manchar smooth bromegrass, crested wheatgrass, and intermediate wheatgrass. The straw mulch was removed before applying seed and replaced immediately after. This procedure helped assure consistency in erosion measurements over time during preceding time periods, but would not be followed in production operations. Tree seed, treated to reduce rodent losses, was applied at a rate of 2.5 pounds per acre, or 275 seeds per plot. Seeds were hand placed through the mulch on each plot to assure contact with the soil surface and to provide proper spacing.

Excessive use by both deer and elk occurred on the study area, especially on the straw-mulched plots, following plot installation in April 1968. This use resulted from failure to recognize the study area as a major migration route and concentration area for big game. Such use continued throughout much of the following summer in spite of concentrated prevention efforts with various kinds of repellents. Intensive animal use caused considerable trampling damage, especially on mulched plots. A gameproof fence was installed around the study plots in early September 1968 to prevent further damage. However, growth and mortality measurements in October showed that 40 percent of the planted trees had died primarily because of trampling by big game. At this time, all trees were carefully mapped to assure future identification. The following spring (April 1969) 2-0 trees were replanted by the same method as before (including fertilization) at all open locations in the plots. This procedure again provided a complete study, but the fence prevented the confounding effect of big game use.

Data Collection

Beginning in 1969, growth and mortality data were collected each year during late August, following the active growth period of ponderosa pine. Because two populations were sampled, it was necessary to record growth separately for all 1968- and 1969-planted trees. A tree was considered dead if it exhibited no green needles at the time of sampling. Height was measured from the top of the previous year's terminal bud scar to the top of the present year's leader bud. Seeded-tree survival was recorded by counting all green trees that were visible above the mulch. Seeded grass survival was obtained by counting the number of live plants occurring in a 1-square-foot circular plot placed at 10 equal intervals along the long axis through the center of each plot.

Beginning in 1969, plot troughs were cleaned about May 30 of each year to evaluate overwinter erosion rates. Troughs for all unmulched plots were cleaned approximately once a week throughout the summer and early fall. Weekly cleaning was necessitated by the higher erosion rates occurring on these plots. A recording rain gage was operated on the study site throughout the summer-fall servicing period. Prior to snowfall, on about October 15, all plots were cleaned again in preparation for winter.

All growth, survival, and erosion data were recorded on schedule until October 1972, which provided 4 years of data for growth and survival and 3-1/2 years of data for erosion.

RESULTS

Plant Survival

Planted-tree survival was excellent on all plots throughout the 4-year study period (table 1). To illustrate, 6 of the 18 study plots had 100 percent survival at the end of 4 years and only 2 plots had less than 95 percent survival.

An average of 12 percent of the tree seeds placed on the plots at the start of the study resulted in countable trees at the end of the first year; after 4 years, this figure had dropped to 5 percent (table 1). More trees were counted the third year than the second. Causal factors probably include sampling error and the possibility that natural seeding occurred from nearby trees. By the end of the study, there were far fewer trees per acre on seeded plots than on planted plots. This, coupled with reduced vigor of seeded trees on both fertilized and unfertilized plots, resulted in greatly reduced canopy cover on seeded tree plots as compared to planted tree plots (fig. 3, 4, and 5).

Plant density on the seeded grass plots decreased rapidly from over 17 plants per square foot the first year to less than 1 plant per square foot the fourth year. Such decreases are common on road fills seeded to grass in the vicinity. However, the lack of vigor evidenced by the limited crown development on the grass plants in figure 6 was not expected. Lack of vigor was probably the result of a severe grasshopper infestation that occurred in this area during both 1971 and 1972. Grasshoppers seriously damaged most shrubs, forbs, and grasses in the area, but had little effect on pine trees.

Table 1.--*Average plant survival by years on granitic road fills*

Year	Planted trees		Seeded trees		Seeded grass
	Percent	*Number/acre*	*Percent*	*Number/acre*	*Plants/ft²*
1969	98.5	13,199	12.2	6,700	17.2
1970	97.9	13,118	9.3	5,133	2.6
1971	97.8	13,105	10.0	5,500	1.2
1972	96.9	12,985	5.0	2,767	0.8

*Figure 3.--Planted ponderosa pine (*Pinus ponderosa*) at 1.5-foot spacing with mulch and fertilizer. (Photo taken May 1972.)*

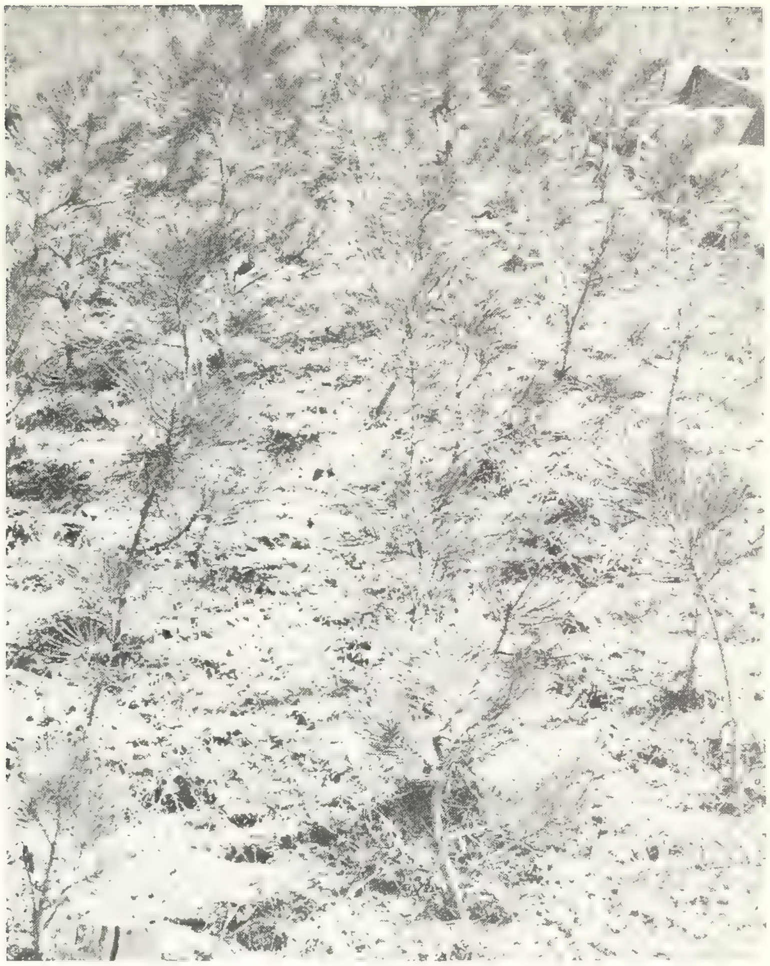

*Figure 4.--Planted ponderosa pine (*Pinus ponderosa*) at 2.5-foot spacing with mulch and fertilizer. (Photo taken May 1972.)*

*Figure 5.--Seeded ponderosa pine (*Pinus ponderosa*) with mulch and fertilizer. (Photo taken May 1972.)*

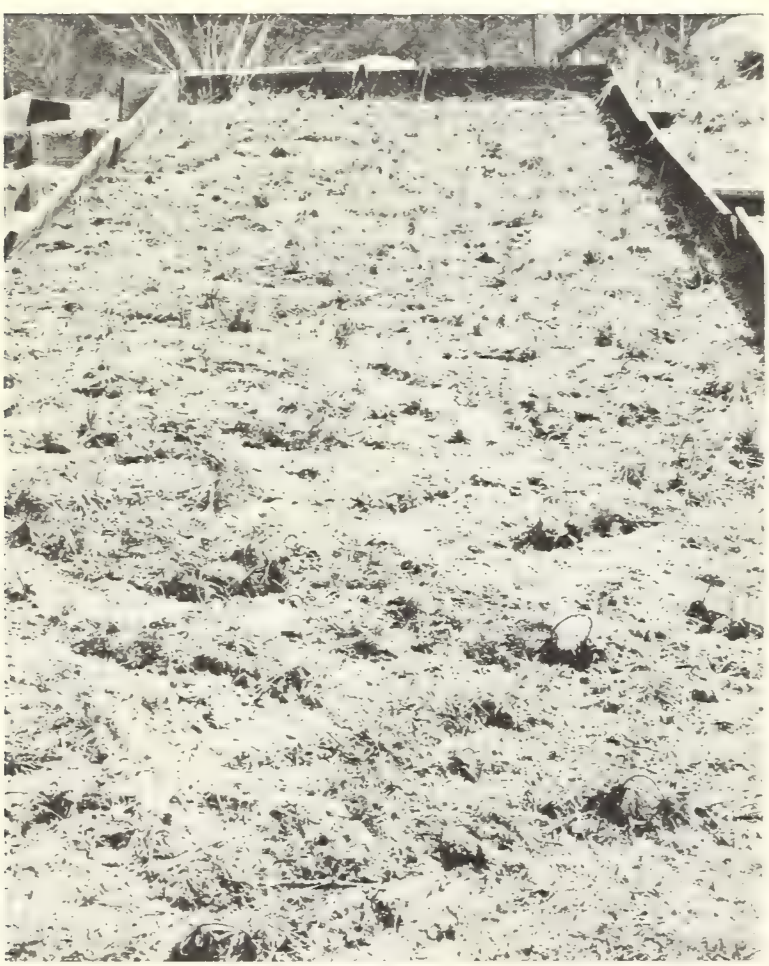

Figure 6.--Seeded grass with mulch and fertilizer. (Photo taken May 1972.)

Height Growth of Planted Trees

Height-growth data were recorded separately for individual trees planted in 1968 and 1969, in the likely event that the two populations were not comparable (statistical analysis of the data verified that they were not). A standard analysis of variance was conducted for each year of each data set. Results are summarized in table 2.

There were highly significant differences in growth on the three replications in both data sets for all years. Differences were caused by replication 1 which consistently had higher growth than replications 2 and 3. Based on an overall average, replication 1 had 42 percent greater growth than replications 2 and 3. Replication 1 was the block of plots in the upper one-fourth of the road fill; the other two replications were lower on the fill slope (fig. 2). Apparently, tree growth tends to be greater in the upper portions of the fill slope, possibly in direct response to greater depth of fill materials and increased moisture collected on the road surface. Similar trends in growth of ponderosa pine with soil depths have been noted on natural soils by investigators cited earlier.

Average annual height-growth values for all years in each data set are plotted on figure 7. Curves to illustrate apparent time trends are shown to facilitate interpretation. Notice the low growth and especially the low treatment effect during the first year after planting the 1968 trees; similar results were not obtained for the 1969 trees. The difference might be explained by the fact that the 1968 trees were planted about 1 month late because of the time required to construct erosion plots; the 1969 trees were planted on schedule.

Figure 7 also shows that growth tends to decrease after 1970. This result differs from that observed by Hall and Curtis (1970), who reported that the rate of seedling height growth increased steadily the first 10 years for plantings in the Town Creek area of the Boise National Forest. However, Lynch (1958) showed that height growth of ponderosa pine decreased markedly as competition between trees increased. Thus, the decreasing growth trend found in this study apparently resulted from increased competition as closely spaced trees grew larger (fig. 3 and 4).

The overall treatment effects (table 2) were statistically significant for all years in both data sets, mostly at the 99 percent level. In order to better define treatment effects, individual treatments were compared against one another using Hartley's multiple range test procedure (Snedecor 1956, p. 253). The effects of fertilizer are immediately apparent on figure 7. Growth on fertilized plots was significantly greater (95 percent level) than growth on all unfertilized plots in all data

Table 2.--*Level of significance obtained from analysis of variance tests for the effects of treatments and replications on height growth*

Year	1968 Trees		1969 Trees	
	Replication	Treatment	Replication	Treatment
	Percent			
1969	99	95	--	--
1970	99	99	99	99
1971	99	99	99	99
1972	99	95	99	99

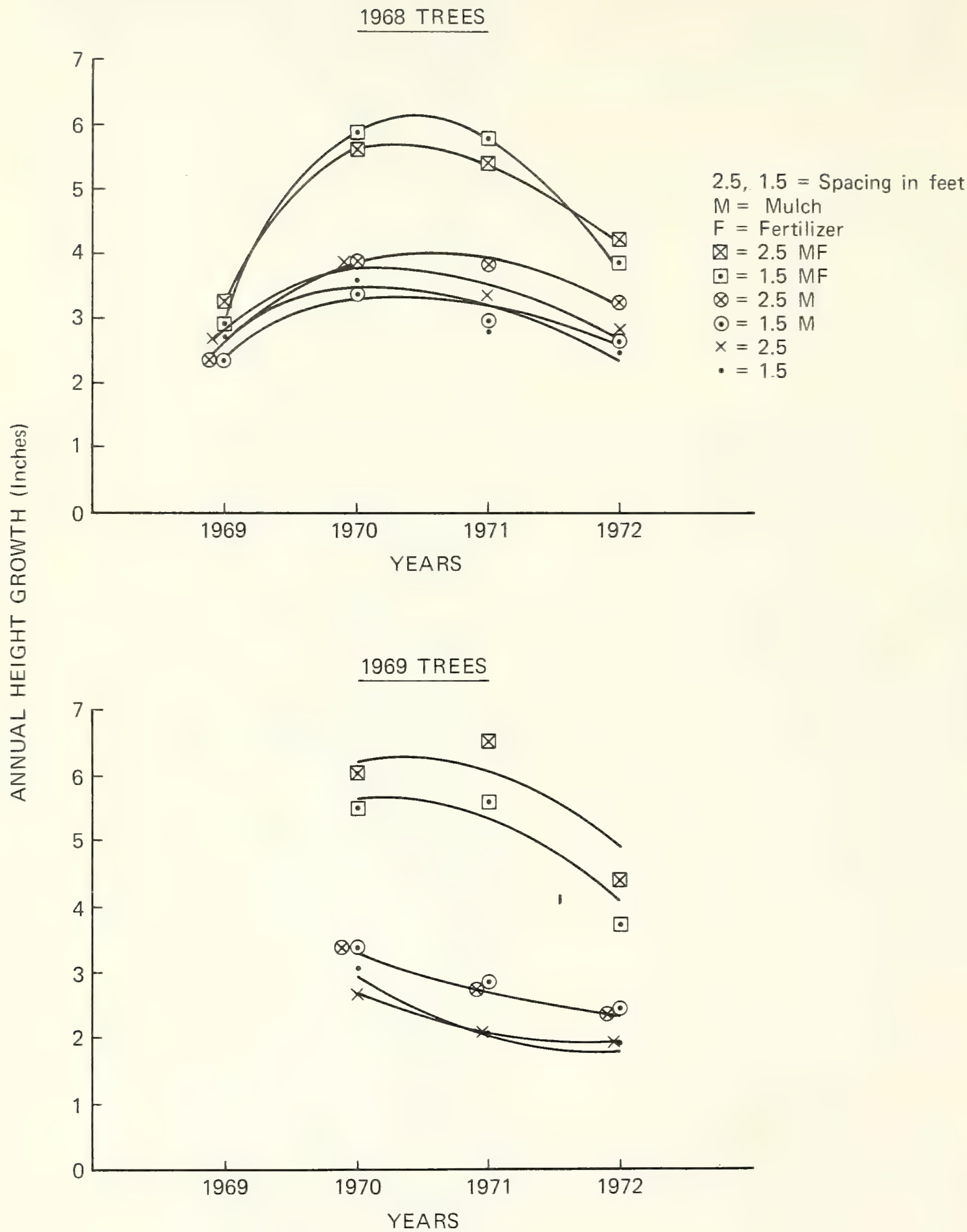

*Figure 7.--Average annual height growth of ponderosa pine (*Pinus ponderosa*) with various combinations of spacing and treatment for all study years.*

Table 3.--*Average percent increase in height growth following fertilization of ponderosa pine on granitic road fills*

Year	1968 trees	1969 trees
	- - - - - - - - - *Percent*	- - - - - - - - -
1969	32	--
1970	60	71
1971	70	116
1972	38	68

sets, except those for 1969 and 1972 on the 1968 trees. Even in these years, however, fertilization did increase growth over some unfertilized plots. Mulching appears to have increased growth somewhat, especially for the 1969 trees; however, increases were significant only at the 90 percent level, and then in but a few cases. Wider spacing also tended to increase growth in some instances, but again increases were detected only at the 90 percent level.

Table 3 was developed to present a clearer picture of average fertilizer effects. Growth is expressed as the average percent increase in growth on plots treated with mulch and fertilizer compared to plots treated with mulch alone. There is a tendency for fertilizer effects to decrease 3 to 4 years after application. Although fertilizer was effective in increasing growth on both sets of trees, the effect was greatest on the 1969 trees. The additional growth increase was probably caused by the fact that a second fertilizer pellet was used when trees were replanted in 1969. This type of fertilizer releases nutrients slowly; some original tree pellets placed in 1968 were still recognizable at the time of planting in 1969. Thus, the 1969 trees received more fertilizer than the 1968 trees.

Erosion Control

Erosion data were summarized by water years (Oct. 1-Sept. 30) beginning in October 1969; consequently, data were provided for 3 complete years, 1970, 1971, and 1972. Additional data were available for the summer of 1969, but were not analyzed because of undue soil disturbance resulting from plot maintenance during the period.

Previous studies (Megahan and Kidd 1972) indicated that the standard deviations of data from erosion plots similar to those used in the present study tend to be proportional to the mean. Consequently, a log (X + 1.0) transformation of erosion data was used to provide a more reliable statistical test of treatment effects.

Statistical analyses were made for each year of data and included a standard analysis of variance to detect overall treatment and block effects and a sequential multiple range test to compare individual treatment effects.

Analysis of variance showed highly significant treatment effects (99 percent level), but no block effects for all years of data tested. Results of the multiple range tests are summarized in figure 8. Variations in erosion by years primarily reflect annual variation in erosion energy available from raindrop impact and wind. No significant differences in erosion were observed among the various mulched plots nor the 1.5- by 1.5- and 2.5- by 2.5-foot unmulched plots. Compared to control plots, planted trees without mulch reduced average annual erosion rates by 48, 32, and 51 percent in 1970, 1971,

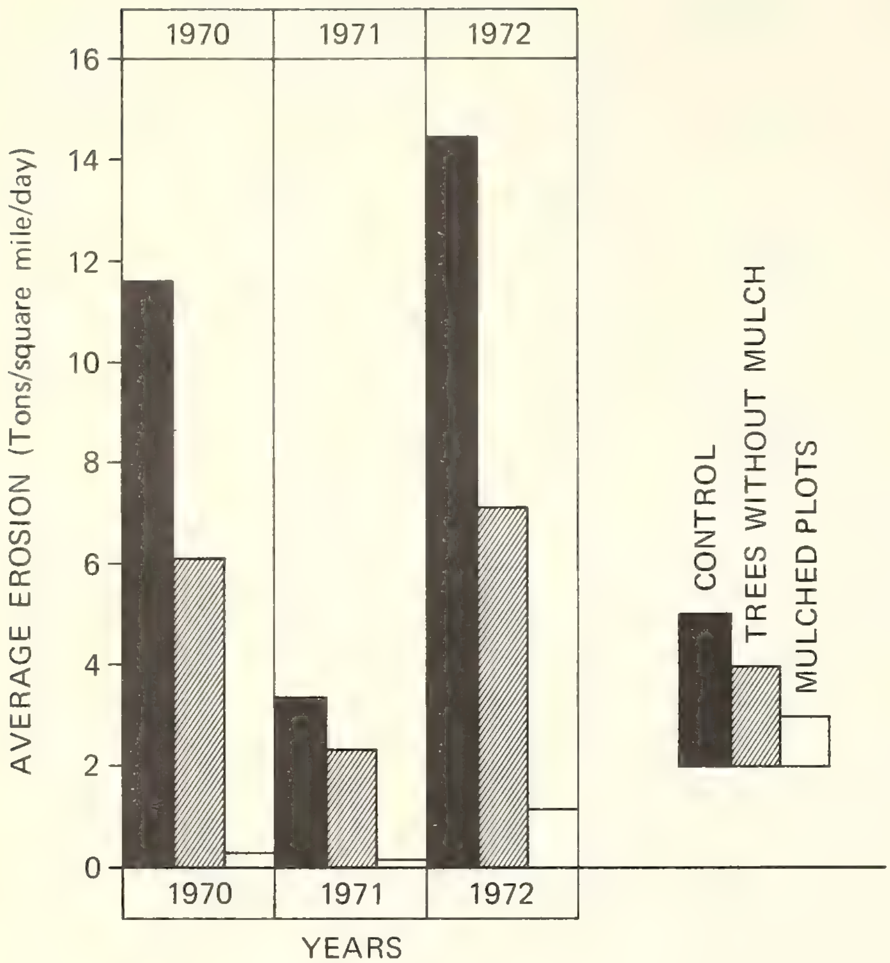

Figure 8.--Average annual surface erosion by treatment on granitic road fills.

and 1972, respectively; reductions were significant at the 95 percent level in 1970 and 1972 and at the 90 percent level in 1971. Mulches caused a highly significant reduction in erosion that averaged about 95 percent of that occurring on the control plots for the 3 years of data.

Mulch effects would be expected to lessen over time as the mulch material deteriorates. Slight time trends did appear on most plots; overall average reductions in erosion of 98, 94, and 92 percent were recorded for the 1970, 1971, and 1972 water years, respectively. Similarly, the growth of trees on the unmulched plots would be expected to provide greater erosion protection over time; however, no consistent time trends were detected nor were block effects with respect to erosion, even though growth averaged about 40 percent higher in the block located near the top of the road fill.

DISCUSSION AND CONCLUSIONS

Mass failure of road fills is an important component of the overall erosion process on slopes in the Idaho Batholith. A large body of studies elsewhere indicate that deep-rooted vegetation, including trees and shrubs, should increase the mass stability of fill slopes. Ponderosa pine possesses a number of attributes that makes it particularly attractive for this purpose. In this study, the intrinsic value of ponderosa pine for increasing the mass stability of fill slopes was accepted as fact and two logical followup questions were investigated: (1) how well does ponderosa pine survive and grow on roadfills and (2) how well does ponderosa pine control surface erosion on road fills?

Performance of planted and seeded ponderosa pine and a seeded grass mixture was evaluated. Survival of the planted pine was high, averaging about 97 percent after four growing seasons. Growth and vigor of the planted trees far exceeded that of the seeded trees and grass. Poor grass responses were atypical, probably the result of a severe grasshopper infestation during 1971 and 1972. Fertilizer increased the annual growth of planted pine by an average of about 95 percent during the year of peak effect. There was some indication that fertilization effects tended to decrease after 3 or 4 years; however, growth still averaged about 45 percent greater than that of trees on unfertilized plots.

Wider spacing of planted trees also tended to increase growth, but not consistently. There was an overall decrease in growth over time that was probably caused by intertree competition. Increasing tree spacing from 1.5 by 1.5 to 2.5 by 2.5 feet did not increase erosion. Considering growth responses, planting costs, and comparable erosion, the 2.5- by 2.5-foot spacing is preferable. Actually, 3- by 3-foot or even 4- by 4-foot spacing should reduce the possibility of growth stagnation and probably would still provide effective erosion control.

Straw mulch held in place by netting was by far the most effective means of reducing surface erosion. Effects were similar on both the tree and grass plots. Mulch effects tended to diminish slightly over time, but even after 3 years, mulch reduced erosion an average of 92 percent. Mulches provided additional benefit by increasing tree growth on many plots. Planted trees alone provided surprisingly large decreases in annual erosion rates, ranging from 32 to 51 percent.

In conclusion, planting ponderosa pine at 3- by 3- to 4- by 4-foot spacings is recommended as an erosion control measure on granitic road fills. If at all possible, trees should be fertilized to accelerate growth, especially root growth. Trees alone should reduce surface erosion by approximately one-third; additions of straw mulch, held in place by erosion net, will reduce surface erosion by about 95 percent.

Logistical problems should be minimal in road fill tree planting on an operational scale. Certainly, access is optimal. Moreover, many roads are constructed in connection with timber sales that require tree planting anyway. Good planting procedures, similar to those prescribed for timber sales, should be used. Planting stock of proper age should be as large as practicable, especially for new road fills.

Ponderosa pine appears as a climax or seral species in a variety of habitat types on natural slopes (table 4). Fill slopes may not be the same habitat type as the original slope because of the severity of the change in overall site conditions. However, the habitat type concept does provide a logical stratification of the site potential for the area. Thus, it is suggested that table 4 be used as a guide for planting ponderosa pine on road fills based upon the forest habitat type found on adjacent undisturbed slopes. Ponderosa pine is not suited for roadbed planting in the various alpine fir (*Abies lasiocarpa* (Hook.) Nutt.) habitat types; lodgepole pine (*Pinus contorta* Dougl.) is recommended for these areas.

Table 4.--*Role of ponderosa pine (*Pinus ponderosa*) in habitat types in central Idaho. (Work by Robert D. Pfister, Robert Steele, and others. Unpublished reports on file at Forestry Sciences Laboratory, Boise, Idaho.)*

Habitat types and phases	Major climax	Minor climax	Major seral	Minor seral
Pinus ponderosa series				
Pinus ponderosa/Agropyron spicatum	X			
Pinus ponderosa/Festuca idahoensis	X			
Pinus ponderosa/Purshia tridentata	X			
Pinus ponderosa/Symphoricarpos albus	X			
Pinus ponderosa/Symphoricarpos oreophilus	X			
Pseudotsuga menziesii series				
Pseudotsuga menziesii/Agropyron spicatum		X*		
Pseudotsuga menziesii/Festuca idahoensis		X*		
Pseudotsuga menziesii/Carex geyeri			X*	
Pseudotsuga menziesii/Calamagrostis rubescens			X*	
Pseudotsuga menziesii/Spiraea betulifolia			X	
a. Carex geyeri phase			X*	
b. Calamagrostis rubescens phase			X*	
Pseudotsuga menziesii/Symphoricarpos oreophilus				
a. Prunus virginiana phase		X*		
Pseudotsuga menziesii/Symphoricarpos albus			X	
Pseudotsuga menziesii/Physocarpus malvaceus			X*	
Pseudotsuga menziesii/Acer glabrum			X*	
Abies grandis series				
Abies grandis/Clintonia uniflora				X
Abies grandis/Vaccinium globulare				X
Abies grandis/Spiraea betulifolia			X	

*These habitat types extend beyond the natural range of ponderosa pine; therefore, ponderosa pine should not be used unless it occurs on undisturbed slopes in the area. Instead, selected shrub species should be investigated.

One final point is of interest. Earlier, it was pointed out that ponderosa pine is an important commercial species. Needless to say, the growing of sawtimber on road fills is not being advocated; however, road fill planting does permit some provocative possibilities for Christmas trees. Certainly, access is good for both the forest manager and the consumer. A number of forest managers have indicated an interest in this aspect of tree planting on road fills. The possibilities are worthy of further consideration, as long as the primary objective, tree planting for erosion control, is maintained.

This study showed that planting of deep-rooted vegetation (ponderosa pine) reduces surface erosion. Such plantings offer additional benefit over more conventional grass seeding because they lessen mass erosion hazards. However, deep-rooted vegetation should not be construed as a panacea for mass erosion on road fills because it will not prevent all landslides, nor substitute for careful road location, design, and construction practices. Tree planting does provide an additional safeguard that should be seriously considered.

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WALTER F. MEGAHAN
1974. Deep-rooted plants for erosion control on granitic road fills in the Idaho Batholith. USDA For. Serv. Res. Pap. INT-161, 18 p., illus. (Intermountain Forest & Range Experiment Station, Ogden, Utah 84401.)

The study was installed in 1968 and continued through 1972. Tree survival averaged about 97 percent after four growing seasons. Fertilizer increased planted tree growth an average of 95 percent during the year of peak effect. Tree planting, coupled with straw mulch and erosion netting, reduced erosion an average of about 95 percent over 3 years. Planted trees alone provided surprisingly large reductions in erosion, ranging from 32 to 51 percent. Planting ponderosa pine at a spacing of 3 by 3 to 4 by 4 feet is recommended as an erosion-control measure for granitic road fills in the Idaho Batholith.

OXFORD: 116; 116.65. KEYWORDS: erosion control, seeding, Idaho Batholith, granitic soil, fertilizer, mulching, tree growth, tree survival.

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Headquarters for the Intermountain Forest and Range Experiment Station are in Ogden, Utah. Field Research Work Units are maintained in:

- Boise, Idaho
- Bozeman, Montana (in cooperation with Montana State University)
- Logan, Utah (in cooperation with Utah State University)
- Missoula, Montana (in cooperation with University of Montana)
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